CONTROL OF SEDIMENT DISCHARGES AND WATER QUALITY BELOW RECREATION RELATED ROADS

By

Victor R. Hasfurther

David H. Foster

Final Report

Eisenhower Consortium
Cooperative Agreement No. 16-587-GR

September, 1978

CIVIL AND ARCHITECTURAL ENGINEERING

University of Wyoming, Laramie

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Rocky Mountain Forest and Range
Experiment Station
Ft. Collins, Colorado

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Department of Civil and Architectural Engineering
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CONTROL OF SEDIMENT DISCHARGES
AND WATER QUALITY BELOW RECREATION
RELATED ROADS

INTRODUCTION

"Sediment from logging roads is the Number 1 water quality problem related to logging activity in the Northwest. Improper road construction may cause surface erosion, mass soil movement, and stream channel erosion. Other related impacts can include temperature increases, reduced dissolved oxygen, and stream pollution from road chemicals" (USEPA, 1975). Numerous other reports have substantiated the fact that forest roads, whether for logging or recreation, greatly increase sediment movement and in many cases degrade stream water quality where the forest road crosses or closely parallels the stream (Haupt and Kidd, 1965; Packer, 1967; Fredriksen, 1970; Leaf, 1970; Anderson, 1971; Brown and Krygier, 1971; Megahan and Kidd, 1972; and Megahan, 1977).

When vegetation is stripped away, the soil is exposed and may be eroded both from the road surface and side slopes by the action of wind, rain or snowmelt (ASCE, 1965). Figure 1 shows the results which have

Figure 1. Road Surface Erosion on Spring Creek Road, 1977.

occurred to a timber harvest road in the Medicine Bow National Forest one year after stripping away the vegetation. The road has not been completed. Timber harvesting is increasing along with the demand for recreational use in the forests of the Western United States resulting in increased road construction activities. Thus, there is the potential for increased deleterious effects on the surrounding environment and stream water quality in these forested areas where new and upgraded road construction activities are occurring.

The potential damage that the impact of new and upgraded road construction activity may have on sediment movement and stream water quality must continue to be evaluated on an individual road by road basis and totally within the entire road system. Improvements in road design and stabilization methods for soils where they are actually practiced on the cut and fill slopes of forest constructed roads have shown that the process of sedimentation and stream water quality degradation have been slowed (Packer, 1964; Haupt and Kidd, 1965; Kochenderfer, 1970; Larsen, 1971; Megahan, 1974; USEPA, 1975; Hasfurther and Connor, 1977; Heede, 1977; and Megahan, 1977). However, further efforts are needed to find more efficient and better ways to protect the forest environment from sediment and water quality effects resulting from road construction activities.

Purpose

The purpose of this research was and is (Eisenhower Consortium Agreements 16-696-GR and 16-791-GR) the development and analysis of ways to use natural forest materials (and in some instances in combination with artificial materials) as effective sediment control devices downstream

from new and upgraded forest roads to minimize the movement of road derived sediments and other pollutants to nearby streams.

Objectives

The specific objectives to be accomplished by this research were:

1. evaluation of existing roads for processes involved in transport of sediment from roads to streams.

2. design several types of sediment control devices to use downstream from culverts on newly constructed roads in forested areas.

3. evaluation of leachable soluble mineral and organic matter from disturbed and undisturbed soil areas by sampling runoff at culverts, over adjacent drainage areas and at the receiving water.

LITERATURE REVIEW

Some of the possible causes for accelerated erosion due to road construction activities on forested lands include: (a) removal or reduction of vegetation and protective cover; (b) destruction or disturbance of the natural soil structure; (c) increased gradients of the land surface by construction activities; (d) decreased infiltration rates on and near the road surface; (e) concentration of generated and intercepted waters passing across and under the road; (f) the cut and fill slopes created by road construction; and (g) poor and improper construction and disposal practices (Megahan, 1977).

Megahan and Kidd (1972) conducted a study in Idaho which indicated that due to road construction in their study area (granitic soils), sediment production increased an average of 45 times during the study period of six years. Most important, however, was that they determined that 85 percent of the erosion occurs during the first year after construction. However, Leaf (1966) found that roads constructed on glaciated, metamorphic

materials exhibited only slight accelerated erosion with no significant increases in sediment yields downstream.

Megahan (1977) lists four basic principles which should be adhered to in order to reduce the amount of erosion coming from road construction. These four basic principles are: (a) minimize the amount of disturbance caused by road construction both by controlling total mileage of roads and reduced area of disturbance on roads being constructed; (b) avoid construction in high erosion hazard areas; (c) minimize erosion on areas that are disturbed by road construction by a variety of practices designed to reduce erosion; and (d) minimize the off-site impacts of erosion. Based upon these four basic principles, Megahan gave guidelines for reduction of erosion from road areas. The guidelines were presented in the context of the entire road development process proceeding from broad land use planning through road location, design, construction, maintenance and closure.

A number of studies have concentrated on the control of erosion from a design and stabilization viewpoint. Haupt (1959) conducted a study in which he related various road characteristics (road width, cross ditch spacing, road cut height, road gradient and embankment slope length) along with watershed characteristics (lower slope gradient, aspect of slope exposure and obstruction factor) to the distance sediment would flow downslope. Using a multiple regression model, he developed design charts to aid in the placement of downslope obstructions.

Packer (1967) wrote an excellent paper that went into considerably more detail than the previous Haupt study of 1959. Packer related the same factors, plus some additional ones to the distance it took to cut a 1-inch deep rill on the road surface. Packer related each factor

individually to the 1-inch rill depth distance. Packer also developed design charts to determine required cross drain spacing and distance to the first obstruction downslope for various conditions. Packer and Christensen (1964) developed a handbook for engineers and technicians to determine, for various conditions, proper cross drain spacing and protective strip interval between the roadway and the stream.

Hasfurther and Conner (1977) found that movement of sediment was related to many of the same factors that Packer and Haupt found in their studies. Also, they found that runoff volume has a significant effect beyond the first year after construction of a new road. Efficiency of sediment entrapment at the first obstruction to flow downstream from a culvert was determined to be mounds or depressions, logs, brush or shrubs, standing trees and stumps, rocks and low lying vegetation in decreasing order of effectiveness.

Surface erosion on the disturbed areas of road construction such as cut and fill slopes is high immediately after disturbance and decreases with time. Revegetation and mulching in these areas has proven quite successful (Gallup, 1974; Highway Research Board, 1973). In areas of high erosion hazard, simple seeding of disturbed areas may not be acceptable and transplanting or mulching may be required to achieve good results (Megahan, 1977).

All studies investigated in the literature indicated that the present methods of route location, road construction techniques and road maintenance can affect the amount of eroded soil material that is transported downslope and discharged into a stream. However, it has been the authors observations that present design and construction methods used by forest service personnel for route location, road construction and maintenance

do not consider the influence that these methods may have on sediment and water quality in connection with timber harvest and recreation roads. Roads located in close proximity to streams, as well as poor road construction techniques, can contribute extensive amounts of sediment. Packer (1967) indicated that transport of sediment downslope from a road is influenced mainly by road characteristics that are alterable through design. That is, the amount of sediment reaching a stream may well be within control of the engineer.

The Environmental Protection Agency (1975, 1976) has recently published reports on "Logging Roads and Protection of Water Quality" and "Forest Harvest, Residue Treatment, Reforestation and Protection of Water Quality" which give important key factors which should be considered in planning, design, construction and maintenance of logging roads to help avoid water quality problems.

STUDY AREAS

Two study areas, Sheep Creek Road and Spring Creek Road, were utilized in this research project. The study areas are located on the Medicine Bow National Forest and were selected in consultation with Medicine Bow National Forest personnel.

Sheep Creek Road

Figure 2 indicates the location of the Sheep Creek Road within the Medicine Bow National Forest. The road is located approximately 50 miles west of Laramie, Wyoming in T14N, R80W, 6th Principal Meridian, Wyoming. The road is being built chiefly for timber harvesting purposes but will be used in the future as part of the Medicine Bow National Forest road system. The length of the road is 1.23 miles and has an average

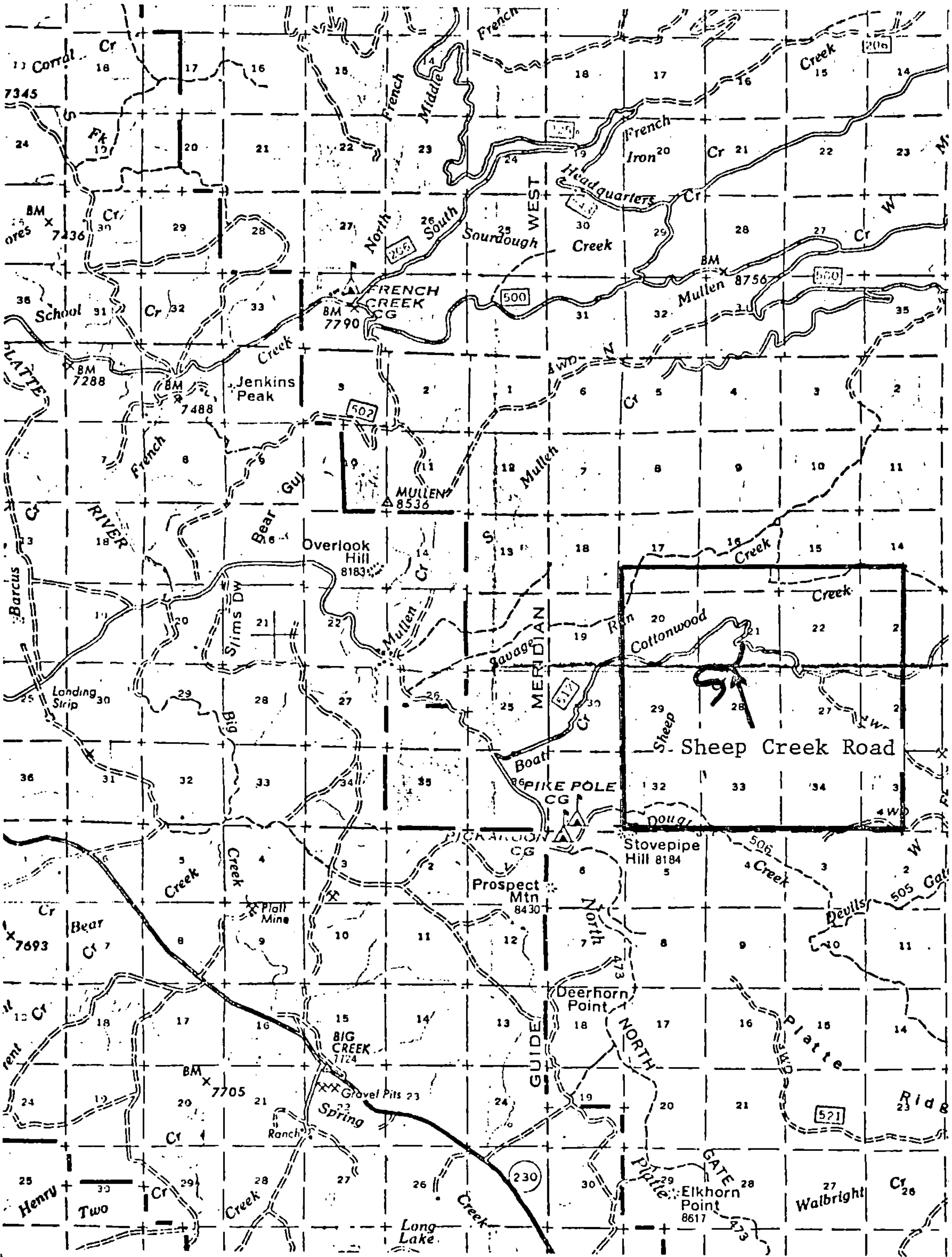

Figure 2. Sheep Creek Road Study Area

elevation of approximately 8860 feet. The proximity of this road to perennial and intermittent stream drainages was a factor in selection.

Construction on Sheep Creek Road began in the early fall of 1976 and was approximately 75 percent completed during 1976. The road was substantially completed by August, 1977. Numerous water bars and out-sloping were used on this road with no drainage ditches on the upstream slope of the road. Only four culverts were placed in the main drainages on the entire road section.

Spring Creek Road

Figure 3 indicates the location of the Spring Creek Road. This road is located approximately 40 miles west of Laramie, Wyoming, in the Medicine Bow National Forest (T16N, R78 and 79W, 6th Principal Meridian, Wyoming). This road is intended for timber harvesting only and will be closed once the timber has been removed. The length of the road is 1.83 miles and averages 10,100 feet in elevation. Numerous perennial and intermittent streams cross the proposed road. The geology (soils) is somewhat similar to that on the Sheep Creek Road.

Construction on this road began in 1975 with clearing and grubbing. Since that time, very little road construction activity has occurred because of the change of ownership of the lease and other mitigating circumstances. It is believed that final construction on the road will occur during the fall of 1978. Nineteen separate culverts are planned for this site with drainage ditches being constructed on the upstream side of the road.

METHODOLOGY

The study areas selected, Sheep Creek and Spring Creek Roads, were based on the availability of approximately 20 study sites between the

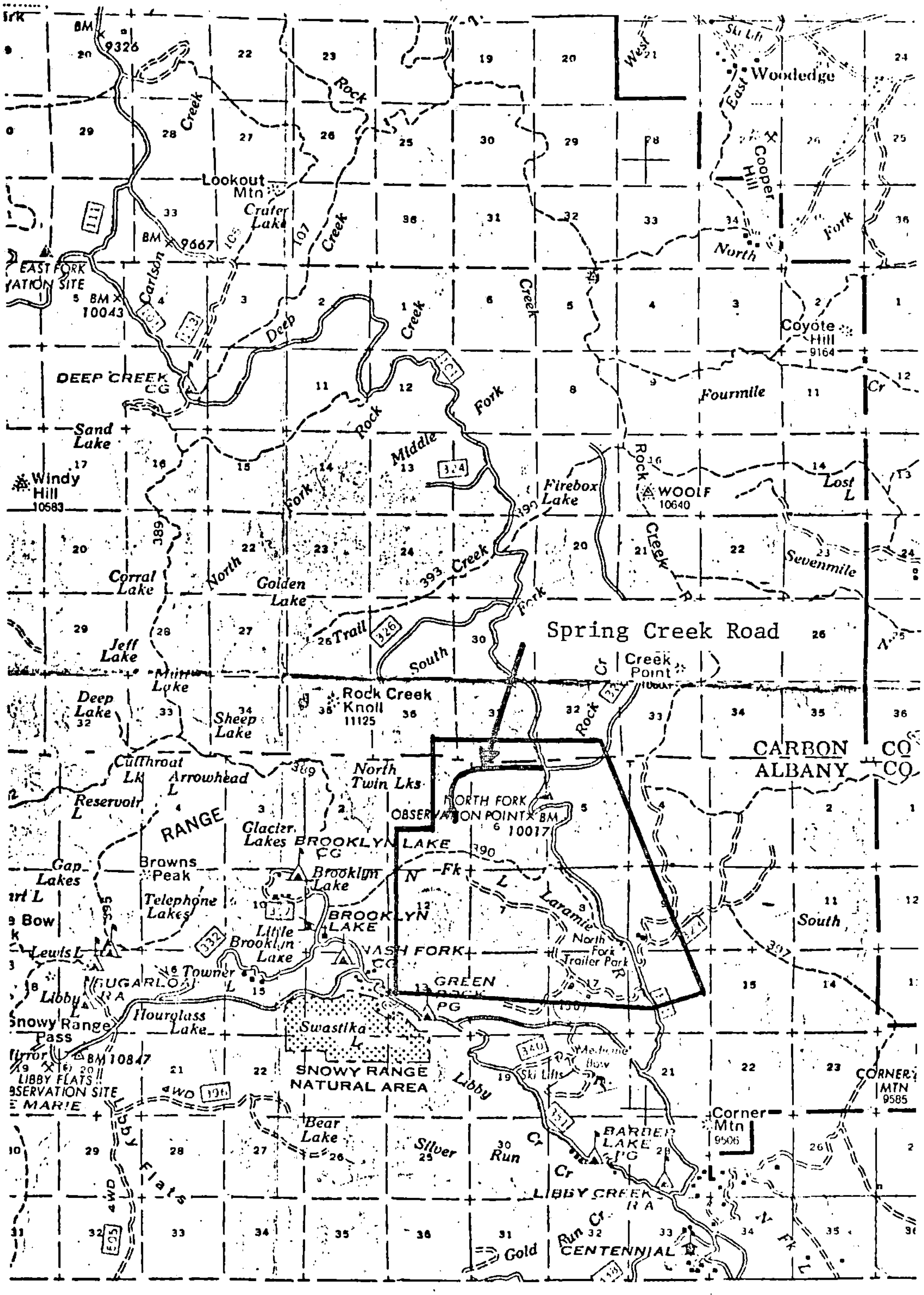

Figure 3. Spring Creek Road Study Area

two areas where sediment control devices could be placed which would meet criteria of the proposed research objectives.

Sediment Control Devices

Sediment control devices of four different classes were selected for investigation in this research study. The four specific classes selected were:

1. Natural vegetation and low lying shrubbery;
2. Logs cut and placed in the drainage, standing trees, dead fall and the like;
3. Depressions and catch basins; and
4. Rocks, earth mounds and gabion structures.

Hasfurther and Connor (1977), Megahan (1977) and Packer (1967) all used these four classes or similar ones in determining protection needed for downslope erosion control below a road. It was desired to find five suitable study sites (a total of 20 study sites) for each of four classes of sediment control device between the two study areas. Proximity of the study sites to perennial or intermittent streams was also used in the selection process for water quality purposes.

Drainage structures, culverts and water bars, were chosen which allowed for all surface runoff and eroded soil originating within the selected road section to be diverted to the study site where the sediment control structures exist. The study site is chosen so that no surface runoff is allowed to continue on down the road but must all be directed to the sediment control structure. Natural topographic drainage divides along the road were used whenever possible. At a small distance below the control device, a stop log device (dam) was constructed to ensure entrapment of essentially all bed load sediment and hopefully a sizable

portion of the suspended sediment load. Table 1 lists all the study sites on the two study areas along with the class of sediment control device. It should be pointed out in Table 1 that only four natural vegetation and low-lying shrubbery study sites were constructed; but six rock, earth-mound or gabion structure study sites exist.

Figure 4 shows a natural vegetation and low-lying shrubbery study site on the Sheep Creek Road. The only modifications done to a natural type site is to construct a barrier (dam) at some distance downstream (50 to 100 feet) of the site to trap any material not trapped by the vegetative cover.

Figure 4. Natural vegetation and low-lying shrubbery control structure on the Sheep Creek Road.

TABLE 1. Sheep Creek and Spring Creek Road Study Area Physical Parameters and Structure Classification.

Station No.	Class of Control Structure	Road Surface Area (Acres)	Average Road Gradient (%)	Cut Slope (H:V)	Fill Slope (H:V)	Contributing Watershed Area (Acres)	Topographic Position	Buffer Zone Slope (H:V)	Soil Classification: % Gravel	% Sand	% Silt and Clay
A. Sheep Creek Road											
1 + 60	Natural vegetation	.138	1.50	None	1.5:1	146.0	West	**	14	80	6
8 + 40	Log Structure	.366	5.70	1.5:1	1.5:1	11.5	North	**	17	76	7
9 + 00	Log Structure	.133	5.70	1.5:1	1.5:1	6.5	North	**	17	80	3
10 + 13	Log Structure	.195	2.20	1.5:1	1.5:1	3.3	North	**	17	76	7
14 + 75	Catch Basin	.219	8.80	1.5:1	1.5:1	8.9	North	**	16	73	11
18 + 75	Depression	.222	9.70	1.5:1	1.5:1	2.3	North	**	6	79	15
23 + 23	Log Structure	.147	5.70	1.5:1	1.5:1	**	West	**	10	82	8
24 + 92	Rock Gabion	.140	2.50	1.5:1	1.5:1	11.5	West	**	10	82	8
27 + 23	Rock Structure and Gabion	.100	5.40	1.5:1	1.5:1	**	West	**	12	84	4
35 + 98	Rock Gabion	.088	4.00	1.5:1	1.5:1	4.9	South	**	20	78	2
36 + 71	Natural vegetation	.084	1.00	1.5:1	1.5:1	**	South	**	20	78	2
44 + 04	Catch Basin	.273	8.00	1.5:1	1.5:1	16.4	Southwest	**	25	73	2
49 + 75	Catch Basin	.269	2.50	1.5:1	1.5:1	**	Southwest	**	25	73	2
B. Spring Creek Road											
7 + 00	Rock Structure and Gabion	.149	2.30	*	*	3.3	South	**	20	72	8
8 + 78	Rock Structure and Gabion	.466	4.60	*	*	8.2	South	**	22	71	7
14 + 50	Log Structure	.195	2.70	*	*	**	South	**	41	56	3
28 + 00	Natural vegetation	.390	7.00	*	*	**	South	**	22	70	8
39 + 00	Natural vegetation	.289	4.00	*	*	**	South	**	20	78	2
52 + 50	Depression	.514	7.50	*	*	23.0	South	**	30	63	7
84 + 00	Rock Structure	.600	5.20	*	*	59.0	East	**	19	76	5

* Actual cut and fill slopes have not been finalized since road construction has not been completed. The slopes will be variable but no slope steeper than 1.5:1 will be allowed except in rock cut sections.

** Detailed road cross-sections or definable contributing water area unavailable. Require field survey to be done in 1978.

[a] Soil classification was done by sieve analysis. Sieves which retain material and are larger than a #10 result in a gravel classification. Sieves between a #300 and a #10 result in a sand classification and material smaller than a #200 sieve is classified silt and clay.

Figure 5. Log structure placed in drainage bottom located on the Sheep Creek Road.

Figure 5 shows a log structure constructed on the study areas. The dead fall logs are cut and placed in the drainage to form a log structure and a series of these log structures are placed down the drainage. A barrier (dam) is constructed below the series of log structures. Natural deadfall and live trees are used in connection with the log structures. The live trees are used for support where possible and also allow for higher log structures to be erected.

Figure 6 shows a catch basin constructed on a steep fill slope on the Sheep Creek Road. It is lined with rock for scour protection. The

Figure 6. Depression basin on a steep fill slope on the Sheep Creek Road.

depression (catch basin) was created by the construction equipment in constructing the road. The actual basin was shaped by shoveling to fit the contour area.

The last class of structures, rocks, earth mounds and gabions, have a variety of ways for construction. Figure 7 shows a rock structure constructed in a manner similar to the log structure of Figure 5. Rocks are piled against other larger rocks and dead fall material to create the series of rock structures. Figure 8 shows a gabion structure. A log support structure is constructed against which is placed a wire mesh structure filled with 1/4 to 1 inch gravel material. The gabion structure does not fit into the surrounding environment as well as the other structures.

Figure 7. Rock barrier control structure located on the Spring Creek Road.

Figure 8. Gabion type control structure located on the Sheep Creek Road.

Physical Parameters

The study sites selected for placement of sediment control devices were analyzed for physical parameters which Hasfurther and Connor (1977) found to be important for roads in the Medicine Bow National Forest. These physical parameters were:

1. Contributing road surface area;
2. Road gradient;
3. Road cut and fill slopes;
4. Soil classification of road material;
5. Contributing watershed area;
6. Topographic position;
7. Buffer zone slope (slope of area below the road drainage structure);
8. Vegetative cover; and
9. Obstructions and depressions to retard sediment flow downstream of the road.

The physical parameters of contributing road surface area, road gradient, road cut and fill slopes, contributing watershed area and topographic position were determined from detailed road plans supplied by the Medicine Bow National Forest and from detailed USGS topographic maps of the study areas. A field verification of the parameters was made to make sure that the road was constructed according to the plans. In those cases where large differences were found, the field measurements were reported in Table 1. The average road gradient slopes shown for the Spring Creek study site are not finalized but due to the amount of preliminary excavation already done for the road they should be close to those shown in Table 1. In a few cases, those quantities left blank in Table 1, the study site topographic and slope survey field measurements are still required. Buffer zone slope in some cases must also be measured in the field with surveying equipment.

Samples of road soil material and sediment trapped at each study site have been and are continuing to be collected. A standard laboratory

sieve analysis is performed on each sample collected for comparison with the sediment being entrapped by the sediment control devices and to determine if some fine soil material may be escaping past the sediment control devices. The sieve range used was 1 1/2", 1", 1/2", #4, #10, #40, #200 and -#200.

Vegetation plots have been established at selected places within each study area for determining cover density and types of plants initially existing in the study area. A field qualitative survey of site vegetation was accomplished at the two study areas by a botanist graduate student. A quantitative study using a canopy coverage method of vegetation analysis was also started in the fall of 1976 (Northwest Science 33:43 1959). Figure 9 shows one of the plant study enclosures on the Sheep Creek Road. Further analysis on the canopy coverage method has not been completed since that time.

Figure 9. Plant study enclosure located on the Sheep Creek Road.

For the four different classes of sediment control devices, the volume of sediment entrapped by each class of device will be statistically analyzed against each other class taking into account the physical parameters at each study site. Multiple correlation and analysis of variance will be used. If these methods are not successful then nonparametric examination of the data will be done. At present, enough quantitative data on sediment entrapped is not available for reliable statistical comparisons with the physical parameters for it to be included in this report.

Field Measurement of Sediment

In order to determine the volume of sediment material at each study site after each year of runoff, the type of sediment control device is established and measurements of distance from the bottom of the fill slope of the road or end of the culvert to the first sediment obstruction of the type established and all subsequent obstructions is measured and the study site area cleaned of all extraneous material. The size of the obstructions at each study site are also determined. A number of transects are then established at each study site (Figure 10) from which the sediment area can be determined by use of a sediment sampler tube (Figure 11) taking sediment depth values across the transect at intervals which will yield the area of sediment at each transect. The sediment volume can then be determined by averaging end areas with distances between transects. Simpson's rule for areas and volume was used in the actual computations. In subsequent years beyond the first year, the above method described for obtaining sediment volume will be used and the difference in volume from year to year will be used as the sediment volume for that year.

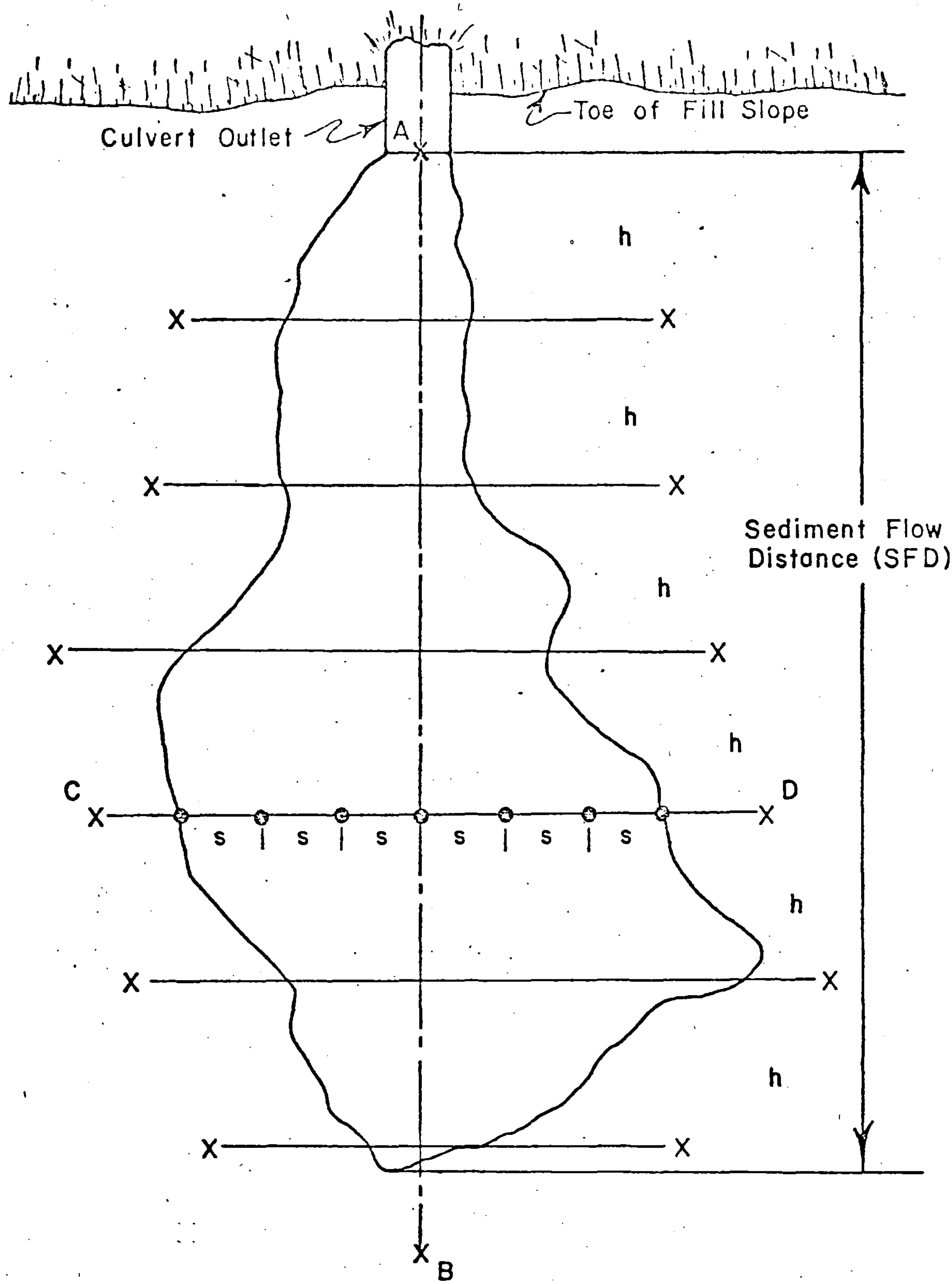

Figure 10. Typical sediment flow pattern and method used to determine sediment volume.

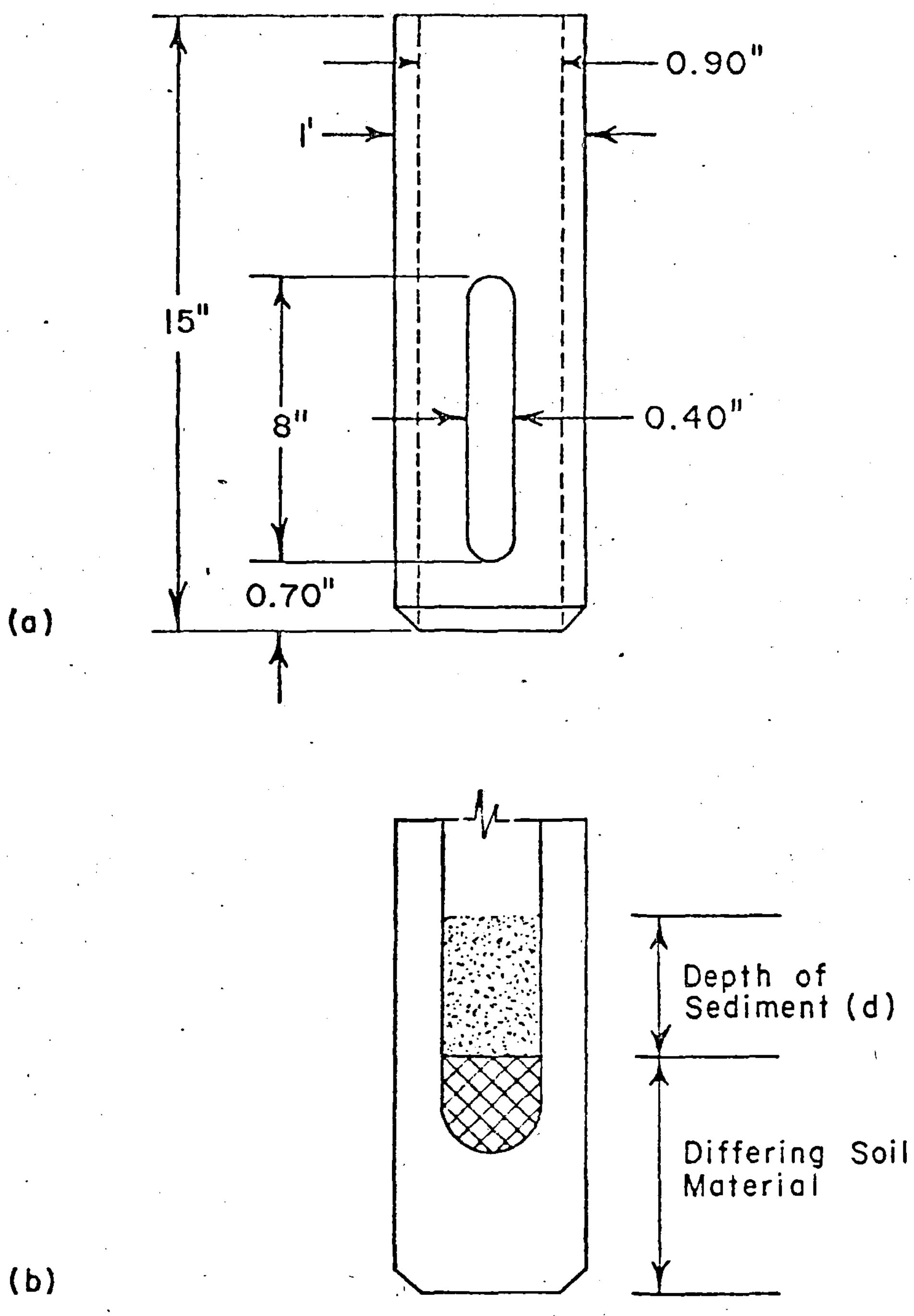

Figure 11. Sampler tube used to determine the depth of sediment.

Water Quality

Assessing the impact of road construction and sediment control on water quality was attacked from both a field and laboratory approach. Field grab water samples (Figure 12) were collected in flowing water near roadway sites at points above and below the road. Above road sampling

Figure 12. Obtaining a water quality grab sample on the Spring Creek Road.

points were located to be away from disturbances arising from road construction activity and from a major portion of dust fall resulting from road use. Generally above road stations were no closer than 35 feet nor more than 80 feet from the road clearing. Sampling points below the road were 15 to 150 feet from the edge of road construction and just beyond (below) the lowest (last) sediment control device.

Sampling points were established at each sediment control area where flow was significant (i.e., greater than a slight seepage). Samples were also taken at points where water was draining but control

devices have not been established as a means of comparison. Samples were taken in clean glass or plastic sample bottles with the mouth facing against the direction of flow to prevent sample contamination. Originally 8 oz. samples were collected but they provided insufficient sample size to perform all analyses which were considered desirable. Samples taken in the field were returned to the University of Wyoming Environmental Engineering Research Laboratory (EERL) and frozen for subsequent analysis.

Samples were analyzed for total dissolved and suspended solids (TDS and SS). The former indicates the quantity of leached salts and soluble matter in the sample water while the latter is a direct measure of the sediment load in the water. Low concentration range Chemical Oxygen Demand (COD) tests to determine the quantity of oxidizable organic matter present which could place a demand on the oxygen reserves of the receiving waters were performed on the grab samples. Volatile solids were also determined as further evidence of the possibility of leached or suspended organics existing in the water. Sample analysis is performed according to Standard Methods for the Examination of Water and Wastewater, 14th Edition (1975). Phosphate was measured by the Vanado-Molybdophosphoric acid method - stannous chloride modification which appears as Method E for phosphate in Standard Methods.

While sediment load carried to the stream may be the major factor in reducing stream quality, a major impact on water characteristics is also likely to arise from the leaching of soluble matter from freshly disturbed soils near the stream. Snow melt itself is relatively low in dissolved salts. Likewise, mountain streams are generally low initially in inorganic constituents, and after an initial "maturing" period, the

stream bed will often contribute little dissolved matter to the waters. This, of course, depends on the geological make-up of the bed materials, water temperature and possibly other factors. Any leached material reaching a stream from nearby culverts would alter water quality since initial quality should be high with respect to dissolved minerals. Calcium, magnesium, sodium and potassium will be determined on drainage and stream samples. These elements may be expected to be major contributors to the inorganic constituents dissolved in water and also have implications if the drainage water should be subsequently used for irrigation.

Laboratory studies investigating the isothermal release of soluble soil components are to be conducted. These studies are not part of this agreement but are to be part of agreement 16-696-GR which is a continuation of this study. In batch studies, distilled water will be used as the eluant and soil samples will be agitated at a speed sufficient to maintain suspension on a gyrorotatory shaker. Agitation will continue until equilibrium is reached and the samples will be centrifuged to remove suspended matter and an aliquot of the supernatant examined for phosphate, COD, Na, K, and TDS. These values may be used as predictors of the soluble pollutants likely to be leachable from a soil surface. Also studies will be carried out using soil columns to which a continuous flow of water will be applied. The data will be used to confirm batch findings as part of the laboratory program.

DISCUSSION, RESULTS AND CONCLUSIONS

This section presents information which was required to satisfy the objectives of this report plus data and results obtained to help in the evaluation of objectives under agreements 16-696-GR and 16-791-GR.

Processes Involved in Sediment Movement

Hasfurther and Connor (1977) found from a study of a number of existing roads in the Medicine Bow National Forest that the major factors that contributed to an evaluation of volume of entrapped sediments was: (a) the road gradient; (b) buffer zone slope; (d) road age; (d) number and type of sediment obstructions; (e) road and watershed drainage area; and (f) runoff volume of a storm event. Megahan (1977) came up with many of these same parameters. In the literature review section of this report are listed those quantities which he felt accelerated erosion from road construction. The authors agree with these findings from their field investigations.

Field investigations of both new and existing roads indicated that almost all the sediment movement which occurs is the result of road construction and the associated logging practices. Figure 13 shows erosion which occurred on the fill slope of the Sheep Creek Road at the end of a water bar. Concentration of the runoff water at this point was a major factor in the erosion process. Figure 1 showed road erosion where the

Figure 13. Erosion of the fill slope on the Sheep Creek Road - 1977.

road was not maintained and construction left for a period of time. In almost all cases where existing roads were analyzed, most of the sediment movement was from the cut and fill slopes of the disturbed road material and the road itself. Where the material above and below the road was undisturbed by road construction activity, minimal amounts of sediment were moved from these areas. In most draws and vegetated channel areas, the main movement of material was organic matter (leaves, pine needles, etc.) in the undisturbed areas.

The steepness of the road along with high cut and fill slope gradients produced the largest rivulets and sediment movement. These steep areas of disturbed road along with clear cut timber harvesting practices above the road area produce by far the largest amounts of sediment movement. This was particularly noticeable on the Sheep Creek Road where small clear cuts are being made directly above the road area and the area is fairly well stripped of its vegetative cover.

Most areas investigated for sediment movement were on a form of granitic type soil. Most areas seemed to have similar patterns of sediment movement from this type of soil.

Construction practices can many times contribute large amounts of sediment and organic matter to nearby streams and vegetated channels. This was quite apparent on the Sheep Creek Road and Spring Creek Road where the contractor was allowed to push slashpiles from clearing and grubbing into the bottom of drainage channels below the road (Figure 14). Once the slashpiles were burned, noticeable amounts of burned organic material (ash) and sediment contained within the slashpiles had been transported downslope. In one case, material was found about one-quarter mile downstream where it entered into a larger perennial drainage. This problem could be alleviated by placing the slashpiles on the ridges

Figure 14. Slashpile on Sheep Creek Road situated in drainage bottom.

and in flat areas where water action would not be as detrimental to the movement of the ash and soil material.

Sediment Control Devices

The methodology used in the design and construction of the sediment control devices was previously explained. The data and information that follows is being used to evaluate the effectiveness of the four different classes of control devices. As stated previously, enough data has not been collected to analyze the effectiveness of these control devices statistically or determine which physical parameters are the most significant in the sedimentation process.

Physical Parameters

Table 1 presented the results of the determinations on road gradient, contributing road surface area, gradients of cut and fill slopes, topographic position, contributing watershed area and buffer zone slope

except as previously directed. The soil classification in Table 1 was obtained from a standard sieve analysis of the road materials. A typical example of the range of material is given in Table 2 for Station 84 + 00 on the Spring Creek Road. The analysis on the soil indicated that a

TABLE 2

Sieve Analysis for Station 84 + 00 - Spring Creek Road

Sieve No.	Weight Retained (lbs)	Percent Passing
1 1/2"	0.485	89.2
1"	0.045	88.2
1/2"	0.115	85.6
#4	0.225	80.6
#10	0.710	64.8
#40	1.570	29.9
#200	1.120	5.1
-#200	0.230	0

large portion of the road material is medium to fine sand. This is also the same material being trapped in the sediment control devices.

The vegetation survey is broken down by study area. For both the Sheep Creek and Spring Creek study areas, the vegetation is categorized by ravine bottoms or drainage sites and upland areas because of the different flora found due to the pressence of water.

I. Sheep Creek Study Area

A. Ravine Bottoms and Other Drainage Sites

The vegetation-type is a mixed conifer forest. The canopy is dominated by *Picea engelmannii*, *Abies lasiocarpa*, and *Pinus contorta*. The understory is dominated by *P. engelmannii*, and *A. lasiocarpa*. The ground cover (including shrubs) is complex, with several species sharing dominance.

B. Upland Sites

The vegetation-type is lodgepole pine forest. The canopy is dominated by *Pinus contorta*. The understory is

dominated by Abies lasiocarpa, with some P. contorta and Picea engelmannii. The ground cover is dominated by Vaccinium scoparium on northfacing slopes and other sheltered sites, and by Carex sp. and V. scoparium on southfacing slopes and other more exposed sites.

II. Spring Creek Study Area

A. Ravine bottoms and Other Drainage Sites

The vegetation-type is spruce-fir forest. The canopy is dominated by Picea engelmannii and Abies lasiocarpa with some Pinus contorta. The understory is dominated by P. engelmannii and A. lasiocarpa. The ground cover is complex with several species shari g dominance.

B. Upland Sites

The vegetation-type is spruce-fir forest. The canopy is dominated by Picea engelmannii and Abies lasiocarpa, with some Pinus contorta. The understory is dominated by P. engelmannii and A. lasiocarpa. The ground cover is floristically simple, and is dominated by Vaccinium scoparium.

Details of the species for each study area as categorized by the botany graduate student as trees, shrubs, or herbs is given in Appendix A.

Sediment Volumes

The sediment volumes obtained from August, 1976 to September, 1977 are listed in Table 3. It should be realized that some areas did not collect sediment on the Spring Creek Road because the area selected has not had a culvert installed to direct runoff water and sediment to the control devices established. Also, one site on Sheep Creek was not constructed until the fall of 1977.

After one year of observation, it can be seen (compare Tables 1 and 3) that the structures which have been observed to trap sediment the best have been the log structures, gabions and catch basins. The natural vegetation and low lying shrubbery also is fairly efficient but takes a much larger and broader area to catch the same amount of sediment as

TABLE 3

Sediment Volumes Trapped 1976-77

Station No.	Volume (ft^3)
A. Sheep Creek Road	
1 + 60	16.03
8 + 40	147.13
9 + 00	47.12
10 + 13	2.77
14 + 75	Destroyed '76 - New 1977*
18 + 75	2.29
23 + 23	7.43
24 + 92	Destroyed '76 - New 1977*
27 + 23	6.77
35 + 98	3.24
36 + 71	None**
44 + 04	16.63
49 + 75	New 1977*
B. Spring Creek Road	
7 + 00	8.42
8 + 78	8.50
14 + 50	0.90
28 + 00	None**
39 + 00	None**
52 + 50	139.57
84 + 00	61.58

*The site was either destroyed by construction in the fall of 1976 and spring 1977 and reconstructed in August of 1977 or was newly constructed in August of 1977.

**No sediment was accumulated either because of poor site choice or culvert not being installed.

the other devices. Rock structures by themselves were a very poor sediment trapping device.

Observation of the sediment control devices over the course of a year indicated that sediment movement can be the result of both snowmelt runoff and intense summer thunderstorms. In areas where little sediment movement had occurred from spring snowmelts, heavy thunderstorms in the summer actually transported as much as 10-20 times more sediment than did the snowmelt runoff. On Sheep Creek Road at Stations 8 + 40, 9 + 00, 23 + 23, 27 + 23 and 35 + 98, minimal amounts of sediment had moved as a result of the spring snowmelt runoff. At all the above stations except 8 + 40, the amount was estimated to be less than 1.0 $ft.^3$ in late June. In July, a large thunderstorm occurred which produced the bulk of the sediment trapped at the above stations that is indicated by Table 3. However, in cases where the drainage area above the road was more than a few acres the movement was about the same or higher for snowmelt events. This was especially noted at Stations 7 + 00, 8 + 78, 52 + 50 and 84 + 00 on Spring Creek Road.

Water Quality

Table 4 indicates the results obtained thus far from the water quality samples. The data are incomplete and any analysis and conclusions drawn here are of a preliminary nature.

In ten cases where complete information is available, five cases show higher suspended solids concentrations below the road construction than above it. Four are higher above and there is one where the values are the same. The average value above the road is 29.4 mg/l while below the road suspended solids show a mean value of 266.2 mg/l. The below

TABLE 4

WATER QUALITY DATA AT SPRING CREEK STATIONS - 1977

Station	Parameter[1]	Location[2]	Date[3] 6/27/77	7/1/77	8/17/77
7 + 00	SS	Above	28	21	*
		Below	10	12	*
	DS	Above	15	50	*
		Below	5	14	*
	COD	Above	27	61	*
		Below	27	28	*
	P	Above	0.236	0.087	*
		Below	0.097	0.097	*
52 + 50	SS	Above	4	NA	*
		Below	NA	101	*
	DS	Above	18	NA	*
		Below	NA	132	*
	COD	Above	27	NA	*
		Below	NA	20	*
	P	Above	0.036	NA	*
		Below	NA	0.091	*
56 + 00	SS	Above	20	*	*
		Below	2358	*	*
	DS	Above	25	*	*
		Below	5	*	*
	COD	Above	10	*	*
		Below	19	*	*
	P	Above	0.035	*	*
		Below	0.046	*	*
57 + 25	SS	Above	35	*	*
		Below	71	*	*
	DS	Above	20	*	*
		Below	95	*	*
	COD	Above	2	*	*
		Below	49	*	*
	P	Above	0.097	*	*
		Below	0.087	*	*

TABLE 4 (Cont.)

Station	Parameter[1]	Location[2]	Date[3] 6/27/77	7/1/77	8/17/77
61 + 65	SS	Above	8	12	30
		Below	12	9	30
	DS	Above	2	13	50
		Below	253	41	75
	COD	Above	18	47	4
		Below	27	24	13
	P	Above	0.076	0.076	0.076
		Below	0.043	0.050	0.104
65 + 40	SS	Above	60	24	56
		Below	95	37	28
	DS	Above	109	148	160
		Below	108	99	130
	COD	Above	8	16	34
		Below	5	17	2
	P	Above	0.065	0.061	0.097
		Below	0.378	0.087	0.087

[1]SS = mg/l suspended solids
DS = mg/l dissolved solids
COD = mg/l chemical oxygen demand
P = mg/l phosphorus

[2]Above = water flowing towards roadway
Below = water flow away from roadway after crossing road right-of-way

[3]* indicates water no longer flowing at sampling station on sampling date.

NA indicates data not available

road value is heavily influenced by one grab sample taken on June 27, 1977 at 56 +00. If the values for both above and below the road for this sampling point are ignored for purposes of analysis, the above road average becomes 30.4 mg/l while the below road mean is 33.8 mg/l. Thus, most of of the difference seen between samples taken above and below road construction depends on one grab sample. While no information is available to suggest that the sample result is fallacious it may be considered suspect since it is more than 20 times higher than any other suspended solids result obtained. The suspended solids results are, therefore, inconclusive at this time. However, they do indicate at this time that on the average a slight increase in suspended solids may be resulting from road construction activities.

The dissolved solids data (Table 4) show an inconclusive pattern similar to suspended solids. Six of ten samples obtained from flowing water at points above the road were higher than samples obtained downstream below the road. On the other hand dissolved solids averaged 82.8 mg/l below the road and 59.2 mg/l above. The values obtained above the road indicate that some leaching of soluble minerals has already occurred prior to the water reaching the road site. The average of nearly 60 mg/l of dissolved matter indicates that the soils are contributing leachable minerals to the water and that this process does not require a disturbed soil to occur. While the below road average is higher than that obtained from samples taken above the road, it should not be completely concluded that road construction per se is increasing the dissolved matter in temporary or permanent streams in the road construction area at this time.

The average COD values are 22.7 mg/l above and 21.1 mg/l below the road. Both are indicative of the presence of organic matter being carried off the forest floor. The road construction does not appear to contribute to this process.

The average phosphorus values are 0.091 mg/l above the road and 0.108 mg/l below the road. Five samples from above showed higher concentration than those from below and the reverse was true for five samples for which data is complete from below the road. Differences do not appear to be significant at this time.

A number of samples were also obtained from the Sheep Creek study area but the analyses have not been completed on the samples. The Sheep Creek samples will be reported in Eisenhower Consortium agreement 16-696-GR.

SUMMARY

Criteria and construction practices which affect sediment movement from road construction in forested areas of the Medicine Bow National Forest have been evaluated. Snowmelt runoff has in general a lesser effect on sediment transport than large summer intense thunderstorms after one year of observation.

Twenty sediment control devices of four different classes have been established on two study areas in the Medicine Bow National Forest. Details on the design and construction of these are reported. An important variable involved in decision making when installing these devices is an economic one. Of course, natural vegetation and low-lying shrubbery areas are the most cost efficient but are unsuitable in most areas because the amount of vegetation, etc. is insignificant and slope

gradients too large. Log structures were found to be the most cost efficient and sediment productive of all devices. Catch basins consumed more man-hours than log structures and gabions required both extra expense for material and more man-hours than either log structures or catch basins. Material availability will be the most critical determining factor under most construction situations. However, where log material is available, log structures will be the most reasonable device to install from both cost and sediment trapping considerations.

Water quality measurements have been started. A number of samples have been analyzed for suspended solids, dissolved solids, chemical oxygen demand and phosphorous for the Spring Creek Road study area. Definite conclusions cannot be drawn from the data at this time. However, in general, the indication is that the suspended and dissolved solids increase while flowing over the road construction area while organic matter is not being contributed from the road area. Water samples for the Sheep Creek Road study area and the leaching experiments have not been completed and will be reported with Eisenhower Consortium agreement 16-696-GR.

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APPENDIX A

VEGETATION CATEGORIZATION

For both the Sheep Creek and Spring Creek study areas, the vegetation is categorized by ravine bottoms or drainage sites and upland areas because of the different flora found due to the presence of water. The species for each study area are categorized as trees, shrubs, or herbs and the letters in parentheses following each name refer to a subjective appraisal of abundance where A - abundant, C = common and UC = uncommon. Only the species of natural or undisturbed areas are listed. Weedy areas along the edges of the newly constructed road areas are not included.

I. Sheep Creek Study Area

A. Ravine Bottoms and Other Drainage Sites

The vegetation-type is a mixed conifer forest. The canopy is dominated by Picea engelmannii, Abies lasiocarpa, and Pinus contorta. The understory is dominated by P. engelmannii, and A. lasiocarpa. The ground cover (including shrubs) is complex, with several species sharing dominance.

Trees:	Picea engelmannii Parry ex Engelm.	(A)
	Abies lasiocarpa (Hook.) Nutt.	(A)
	Pinus contorta Doug. ex Loud. ssp. latifolia (Engelm.) Critchfield	(C)
Shrubs:	Ribes lacustre (Oers.) Poir.	(C)
	Rosa acicularis Lindl.	(C)
	Shepherdia canadensis (L.) Nutt.	(C)
	Vaccinium scoparium Leiberg.	(C)
	Alnus Tenuifolia Nutt.	(UC)
	Clematis occidentalis Hornem.	(UC)
	Juniperus communis L.	(UC)
	Lonicera involucrata (Rich.) Banks ex Spreng.	(UC)
	Rubus idaeus L.	(UC)
	Salix sp.	(UC)
Herbs:	Carex sp.	(A)
	Erigeron peregrinus (Pursh) Greene	(A)
	Fragaria virginiana Duchesne	(A)
	Mosses	(A)
	Pyrola sp.	(A)
	Agropyron spicatum (Pursh) Scibn. & Smith	(C)

Arnica cordifolia Hook.	(C)
Berberis repens Lindl.	(C)
Bromus ciliatus L.	(C)
Deschampsia caespitosa (L.) Beauv.	(C)
Galium boreale L.	(C)
Galium triflorum Michx.	(C)
Geranium richardsonii Fisch. & Trautv.	(C)
Ligusticum porteri Coult. & Rose	(C)
Taraxacum sp.	(C)
Trisetum spicatum (L.) Richt.	(C)
Trisetum wolfii Vasey	(C)
Aconitum columbianum Nutt	(UC)
Anaphalis margaritaceau (L.) Benth. & Hook.	(UC)
Astragalus sp.	(UC)
Campanula rotundifolia L.	(UC)
Epilobium angustifolium L.	(UC)
Gentiana amarella L.	(UC)
Heracleum lanatum Michx.	(UC)
Hieracium albiflorum Hook.	(UC)
Linnaea borealis L.	(UC)
Liverworts (Marchantia sp.?)	(UC)
Lupinus argenteus Pursh	(UC)
Mitella pentandra Hook.	(UC)
Osmorhiza depauperata Phil.	(UC)
Senecio serra Hook.	(UC)
Trifolium parryi Gray	(UC)
Vicia americana Muhl. ex Willd.	(UC)
Zigadenus elegans Pursh	(UC)

B. Upland Sites

The vegetation-type is lodgepole pine forest. The canopy is dominated by _Pinus contorta_. The understory is dominated by _Abies lasiocarpa_, with some _P. contorta_ and _Picea engelmannii_. The ground cover is dominated by _Vaccinium scoparium_ on north-facing slopes and other sheltered sites, and by _Carex sp_. and _V. scoparium_ on south-facing slopes and other more exposed sites.

Trees:	_Pinus contorta_ Doug. ex Loud. ssp. _latifolia_ (Engelm.) Critchfield	(A)
	Abies lasiocarpa (Hook.) Nutt.	(A)
	Picea engelmannii Parry ex Engelm.	(UC)
Shrubs:	_Vaccinium scoparium_ Leiberg.	(A)
	Arctostaphylos uva-ursi (L.) Spreng.	(C)
	Juniperus communis L.	(C)
	Shepherdia canadensis (L.) Nutt.	(C)
	Rosa acicularis Lind.	(UC)
Herbs:	_Arnica cordifolia_ Hook.	(C)
	Carex sp.	(C)
	Hieracium albiflorum Hook.	(C)

Linnaea borealis L. (C)
Lupinus argenteus Pursh (C)
Solidago spathulata DC. (C)
Trisetum spicatum (L.) Richt. (C)
Anaphalis margaritacea (L.) Benth. & Hook. (UC)
Antennaria sp. (UC)
Chimaphila umbellata (L.) Bart. var. occidentalis (Rydb.) Blake (UC)
Corallorhiza maculata Raf. (UC)
Epilobium angustifolium L. (UC)
Pterospora andromedea Nutt. (UC)
Pyrola secunda L. (UC)
Senecio eremophilus Rich. (UC)

II. Spring Creek Study Area

A. Ravine bottoms and Other Drainage Sites

The vegetation-type is spruce-fir forest. The canopy is dominated by Picea engelmannii and Abies lasiocarpa with some Pinus contorta. The understory is dominated by P. engelmannii and A. lasiocarpa. The ground cover is complex with several species sharing dominance.

Trees:
Picea engelmannii Parry ex Engelm. (A)
Abies lasiocarpa (Hook.) Nutt. (A)
Pinus contorta Doug. ex. Loud. ssp. latifolia (Engelm.) Critchfield (UC)

Shrubs:
Vaccinium scoparium Leiberg. (A)

Herbs:
Erigeron peregrinus (Pursh) Greene (A)
Arnica cordifolia Hook. (C)
Bromus ciliatus L. (C)
Caltha leptosepala DC. (C)
Danthonia intermedia Vasey (C)
Delphinium barbeyi (Huth) Huth (C)
Deschampsia caespitosa (L.) Beauv. (C)
Hieracium gracile Hook. (C)
Juncus balticus Willd. (C)
Mosses (C)
Senecio sp. (C)
Trisetum spicatum (L.) Richt (C)
Trisetum wolfii Vasey (C)
Veronica wormskjoldii Roem. & Schult. (C)
Achillea millefolium L. (UC)
Angelica grayi Coult. & Rose (UC)
Antennaria sp. (UC)
Carex sp. (UC)
Epilobium angustifolium L. (UC)
Fragaria virginiana Duchesne (UC)
Ligusticum porteri Coult. & Rose (UC)

	Liverworts (*Marchantia sp.*?)	(UC)
	Lupinus argenteus Pursh	(UC)
	Osmorhiza depauperata Phil	(UC)
	Pyrola sp.	(UC)
	Senecio eremophilus Rich.	(UC)
	Trifolium parryi Gray	(UC)
	Zigadenus elegans Pursh	(UC)

B. Upland Sites

The vegetation-type is spruce-fir forest. The capopy is dominated by *Picea engelmannii* and *Abies lasiocarpa*, with some *Pinus contorta*. The understory is dominated by *P. engelmannii* and *A. lasiocarpa*. The ground cover is floristically simple, and is dominated by *Vaccinium scoparium*.

Trees:	*Picea engelmannii* Parry ex Engelm.	(A)
	Abies lasiocarpa (Hook.) Nutt.	(A)
	Pinus contorta Doug. ex Loud. ssp. *latifolia* (Engelm.) Critchfield	(C)
Shrubs:	*Vaccinium* scoparium Leiberg.	(A)
Herbs:	*Arnica cordifolia* Hook	(C)
	Carex sp.	(UC)
	Epilobium angustifolium L.	(UC)
	Mosses	(UC)
	Poa nervosa (Hook.) Vasey	(UC)
	Trisetum spicatum (L.) Richt.	(UC)